International Journal on Emerging Technologies **4**(1): 55-61(2013)
ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Expansive Soft Soil Improvement by Geogrid Encased Granular Pile

***Rakesh Kumar* [*] *and P.K. Jain* [**]**
[*]*Asst. Professor, Department of Civil Engineering, M.A.N.I.T. Bhopal, (M.P.) India.*
[**]*Professor, Department of Civil Engineering, M.A.N.I.T. Bhopal, (M.P.) India.*

(Received 05 February, 2013, Accepted 20 March, 2013)

ABSTRACT: An expansive soil is to be source of trouble to civil engineering as its strength, volume and compressibility changes tremendously on wetting. Different ground improvement techniques have been proposed in the literature to work with this soil and are found to be successful to some degree. The construction of granular piles has been proved successful in improving soft marine clays, which are very poor from strength and compressibility criteria. The expansive soil may also be considered as soft soil under wet condition. The technique of granular pile may be applied in expansive soil too. The granular piles derive their load carrying capacity from the confinement offered by the surrounding soil. In very soft soils this lateral confinement may not be adequate and the formation of the granular pile itself may be doubtful. Wrapping the granular pile with suitable geogrid is one of the technique to improve the performance of granular piles. The encasement by geogrid makes the granular piles stiffer and stronger. The behavior and the mechanism of the granular pile and geogrid encased granular piles are not investigated for expansive soil. This paper is an attempt to investigate the improvement of load carrying capacity of granular pile with and without geogrid encasement through laboratory model tests conducted on single granular pile installed in expansive clay bed prepared in controlled condition in small testing tanks. The load tests were performed on single granular pile. Tests were performed with different diameter of granular piles with and without geogrid encasement. The results from the load tests indicated a clear improvement in the load carrying capacity of clay, with granular pile and with encased granular pile. The increase in the load carrying capacity also increases as the diameter of the granular pile increases.

Key Words: Granular Pile, Expansive Soil, Geogrid.

I. INTRODUCTION

Expansive soil becomes soft on wetting and strength loses results in differential settlement. Hence such soil is avoided, replaced with good soil and soil improving techniques are also adopted in such soils .The soft soil improving technique that could possibly be attempted in soft expansive soil is granular pile (also known as stone column).Studies shows that in soft marine clays, construction of granular piles has proved to be successfully established. The construction of granular pile involves partial replacement of soft soil with about 10 to 35% of granular material in the form of column. The load carrying capacity of the ground increases and settlement decreases significantly and the ground become useable to support the structure. The presence of the granular pile creates a composite material which is stiffer and stronger than the original soil. The granular pile techniques was adopted in European countries in the early 1960s and thereafter it has been used successfully in many parts of the world .Granular piles in compressive loads fail in different modes, such as bulging (Hughes and Withers 1974; Hughes et al. 1975), general shear failure (Madhav and Vitkar 1978), and sliding (Aboshi et al. 1979). A long granular pile having a length greater than its critical length i.e., about 4 times the diameter of the column fails by bulging irrespective of whether it is end bearing or floating (IS:15234: 2003).

The granular pile derives capacity from the confinement of the surrounding soil. When the granular piles are installed in very soft clays, they may not derive significant load capacity due to the low lateral confinement. McKenna et al.1975 reported cases where the stone column was not restrained by the surrounding soft clay which lead to excessive bulging and also the soft clay squeezed into the voids of the aggregate. In such situations, the granular pile itself may need to be provided with additional confinement for its improved performance. One ideal form of providing such support to granular pile (stone columns) is wrapping the individual stone columns using suitable geosynthetic as shown in Fig. 1.

This encasement imparts additional confinement to the stone column and brings in several advantages like increased stiffness of column, preventing the loss of stones into the surrounding soft clay, preserving the drainage and frictional properties of the stone aggregates, etc., as described by Raithel *et al.*2002, Murugesan and Rajagopal 2007a. The concept of encasing the stone column by wrapping with geotextile was proposed by Van Impe in the year 1989. Ayadat and Hanna 2005 have reported the benefits of encasing the stone column installed in collapsible soils. Murugesan and Rajagopal 2007a have performed laboratory model tests on the stone column installed in a unit cell tank.

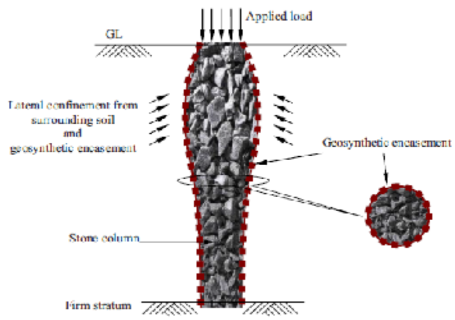

Fig.1. Schematic Diagram of Geosynthetic Encased Granular Pile.

The effect of encasement was found to decrease with an increase in the diameter of the stone column. Malarvizhi and Ilamparuthi 2007 have compared the performance of stone columns with and without geogrid encasement and found the encased geogrid stone column to be more effective.

II. EXPERIMENTAL PROGRAM

Priebe(1995) proposed a method to estimate the settlement of foundation resting on the infinite grid of stone columns (granular piles) based on unit cell concept. In this concept, the soil around a stone column for area represented by a single column, depending on column spacing, is considered for the analysis. As all the columns are simultaneously loaded, it is assumed that a lateral deformation in soil at the boundary of unit cell is zero. Except near the edges of the loaded area, the behavior of all column soil units is the same and thus only one column soil unit needs to be analyzed (Balaam et al.1978).The unit cell concept has also been used by Abhijit and Das (2000) and Ambily and Gandhi (2007).

All experiments were carried out on a 50, 65 and 80 mm diameter granular pile surrounded by soft clay in cylindrical tanks of 250, 325 and 400 mm high and157.5, 204. 75, 252 mm a diameter to represent the required unit cell area of soft clay around each pile assuming triangular pattern of installation of piles(For triangular pattern Equivalent Diameter of Test Tank = 1.05x Diameter of Tank). Tests were carried out with unconfined compressive strength of 50kN/m^2 as summarized in Table 1.

Table. 1. Properties of the Expansive Soil.

Properties	**Value**
L.L.(%)	55
P.L. (%)	30
P.I. (%)	25
Specific Gravity	2.6
Optimum Moisture Content (%)	24.5
Maximum Dry density (kN/m^3)	15.5
Differential Free Swell (%)	55
Classification(IS:1498-1972)	CH
Degree of Saturation	100%
Unconfined Compressive Strength(kN/m^2)@water content 31%	50

A. Test Setup

A typical test arrangement for a single pile test is shown in Fig. 2. The granular pile was extended to the full depth of the clay placed in the tank so that *l* /*d* ratio length of the pile/diameter of the pile is a minimum of four, which is required to develop the full limiting axial stress on the pile column Mitra and Chattopadhyay 1999.

Loading plates used in the tests was circular having a diameter equal to the diameter of the granular pile. The load was applied through a proving ring at a constant displacement rate of 1.25 mm/min. A proving ring is a steel ring of 3kN capacity, the deformation of which is measured using a mechanical displacement gauge to arrive at the axial load applied through the ring.

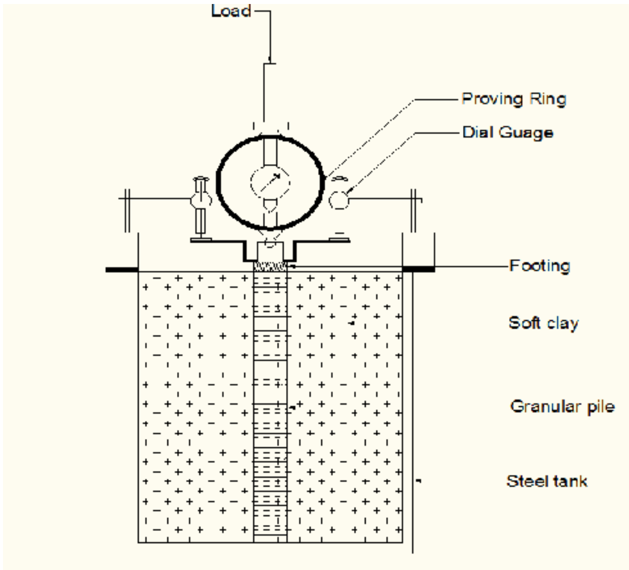

Fig. 2. Load Test on Single Granular Pile in Small Test Tank.

B. Material Properties

Three basic materials used for this study are clay representing the soft soil to be improved, sand, the granular pile forming material and the geogrid for encasing the granular pile. The properties of each of these are as follows:

(i) Expansive Clay: The clay used in the investigation is black cotton soil taken from MANIT Bhopal campus. The soil is air dried, pulverized and passed through 0.075 mm sieve. The soil fraction passing sieve was used in the investigation. Its properties are given in Table 1.

(ii) Sand: Properties of the sand are listed in Table. 2. The shear strength parameters of sand were determined from direct shear tests in small shear box with plan dimensions of 60 mmx60 mm and height of 25 mm.

Table. 2. Properties of River Sand Used for Granular Pile.

Properties	**Value**
Specific Gravity	2.68
D_{10}(mm)	0.34
D_{30}(mm)	0.5
D_{60}(mm)	0.6
C_u	1.76
C_c	1.22
Classification(IS:1498-1972)	SP
Maximum dry Density, γ_{max}(kN/m^3)	17.30
Minimum Dry Density, γ_{min}(kN/m^3)	15.30
Cohesion(kN/m^2)	2.8
Angle of Internal Friction at 65% Relative Density	40.82^0

(iii) Geogrid: Geogrid used has made name Nova net. The properties of the geogrid (net) Manufacturer's data are presented in Table 3. Geogrid were stitched to form the tube for encasing the granular pile.

Table. 3. Properties Of Geogrid Used.

Properties	Value
Aperture Size (mm)	1
Stiffness(KN/m)	15
Weight (gm/m^2)	260

B. Preparation of Soft Soil Bed

The area of the tank is selected in such a way that the loading on the granular pile would not be affected by the tank boundaries. In the present work test tanks of diameters 250mm,210mm and 165mm are taken for installing granular piles of diameter 80mm, 65mm and 50mm respectively. Before filling the soil in to the tank, a thin coat of grease was applied along the inner surface of tank wall to reduce friction between clay and tank wall. The soil filled was having water content as 31%, the value corresponding to soil unconfined compressive strength of 50kN/m^2 determined by unconfined compression test. Clay was filled in layers with measured quantity by weight. The surface of each layer was compacted uniformly by a tamper to achieve a 50 mm height and uniform density of 19.375kN/m^3. Care was taken to ensure that no significant air voids were left out in the test bed.

C. Construction of Granular Pile

Granular pile was constructed by a replacement method. After the soft soil bed was prepared, a casing pipe having an outer diameter equal to the diameter of the granular pile was used to install the granular pile. Thin open-ended seamless steel pipes of 50, 65 and 80 mm outer diameters and wall thickness 2 mm were used in the present case. The casing pipe was pushed into the soil up to the bottom of the tank for making the ordinary granular pile. In the case of encased granular pile, the encasement was provided around the casing pipe. The casing pipe along with the geogrid encasement was slowly pushed in to the clay bed vertically at the central location in the clay surface in the tank until it reaches the bottom of the tank. Only static force was manually applied to push the casing pipe gently into the soil so as to minimize the disturbance in the clay soil that may change the properties of the clay after reinforcement.

Outer surface of the pipe was lubricated by applying a thin layer of grease for easy withdrawal without any significant disturbance to the surrounding soil. Granular material (river sand) was moistened(with 5%of water) before charging into the casing pipe in order to prevent it from absorbing the moisture from the surrounding clay soil. The granular material was charged into the hole through pipe in layers in measured quantities so as to have each compacted fill layer of 50 mm thickness. A layer was compacted by a 2 kg circular steel tamper with 10 blows of 100 mm drop to achieve uniform compacted density. This light compaction effort was adopted to ensure that there is no significant lateral bulging of the pile which may create disturbance to the surrounding soft clay. The corresponding unit weight of granular pile was found to be 17.3 kN/m^3.The pipe was then raised in stages ensuring a minimum of 5 mm penetration below the top level of the placed material. The procedure was repeated until the granular pile was completed to the full height.

D. Test Procedure

The loading plate (i.e. footing) used in these tests were circular, having diameter equal that of the granular pile. The load was applied through proving ring by a motorized mechanism operating at a constant strain rate of 1.25 mm/min. Settlement was monitored by a dial gauge having least count of 0.02mm. The settlement readings up to 20% of the diameter of the footing were recorded. As the loading is quick it is essentially undrained loading which simulates the loading condition immediately after the construction.

Three Series of laboratory model tests were performed. First series of tests were performed on the clay bed without any granular pile. Second series of tests were performed on ordinary granular piles without any encasement. Third series of tests were performed on encased granular piles with different diameters. Table 4 summarizes the testing program of the load tests conducted in the present study.

Table 4. Summary of the Model Load Tests Conducted.

Test Tank Diameter, mm	Footing Plate Diameter, mm	Length of Pile, mm	Remarks Plain Clay (PC), Ordinary Granular Pile (OGP), Encased Granular Pile (EGP)
165	50	Nil	PC
		250	OGP
		250	EGP
210	65	Nil	PC
		325	OGP
		325	EGP
250	80	Nil	PC
		400	OGP
		400	EGP

III. RESULTS AND DISCUSSIONS

A. Effect of Granular Pile Inclusion in Soil

The load-settlement curve obtained from load tests on clay bed, ordinary granular pile and encased granular pile of different diameters are shown in Fig. 3, 4 and 5 respectively for footing diameter (granular pile diameter) 50 mm, 65 mm and 80 mm respectively. It may be noted from these figures that inclusion of granular pile in the soft expansive soil increases the load carrying capacity of the soil. Further, the geogrid encased granular piles perform better than the ordinary granular pile.

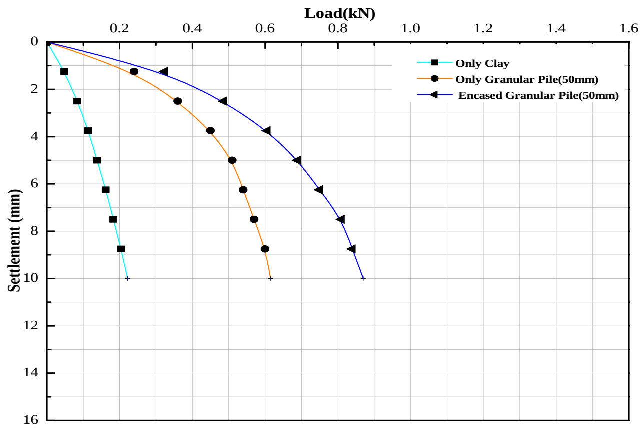

Fig. 3. Load-Settlement Curve of 50 mm Diameter Granular Pile.

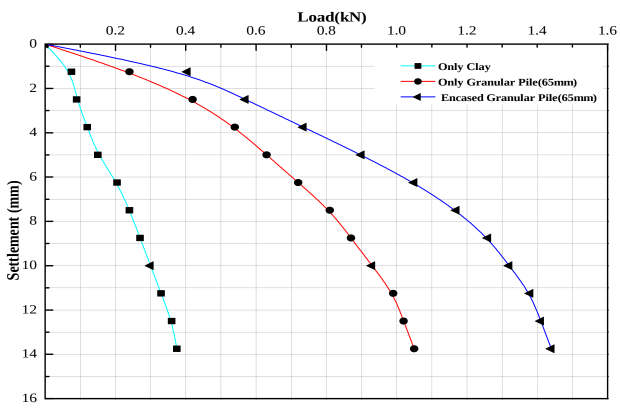

Fig. 4. Load-Settlement Curve of 65 mm Diameter Granular Pile.

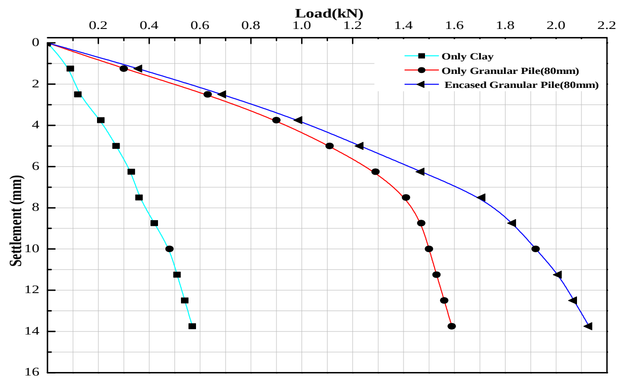

Fig.5. Load-Settlement Curve of 80 mm diameter Granular Pile.

The ultimate load carrying capacity in each case was determined by drawing double tangent to load settlement curve. The obtained values of ultimate load are shown in Fig. 6 and tabulated and compared in Table. 5.

Table 5. Ultimate Load Values.

Footing Plate Diameter, mm	Test Condition	Ultimate Load, kN	Ratio Pp/Pc
50	PC	0.150	-
	GP	0.480	3.2
	EGP	0.720	4.8
65	PC	0.255	-
	GP	0.835	3.27
	EGP	1.200	4.7
80	PC	0.385	-
	GP	1.400	3.63
	EGP	1.730	4.50

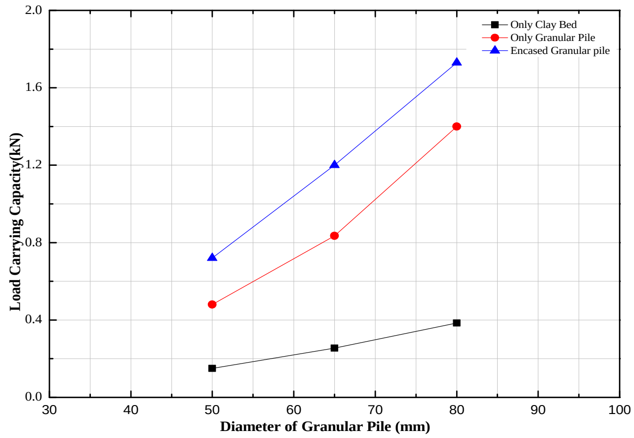

Fig.6. Ultimate Load of Granular Pile with Varying Diameter of Pile.

The ratio Pp to Pc, where Pp is ultimate load value for pile and Pc is ultimate load of the plain soil for the same footing diameter is calculated and given in Table. 5. From this table it may be noted that irrespective of pile diameter, the load carrying capacity of the soil increases by more than three times by installation of granular pile in the soil. Further, encasement of granular pile by geogrid adds additional benefit by enhancing the load carrying capacity to more than four times to that of plain soil.

IV. CONCLUSIONS

The results of the testing program give important insight in to the performance of encased granular piles in expansive clay. The trends obtained in these laboratory tests are in good agreement with the results reported in the literature. The major conclusions that can be drawn from the present study are as follows:

1. Inclusion of granular pile considerably improves the load-settlement characteristics of expansive clay. The ultimate load of clay bed reinforced with granular pile is increased about three times the ultimate load in plane clay bed.
2. The load capacity of the granular pile also increases by encasing the granular pile by geogrid. The ultimate load of clay bed reinforced with encased granular pile is increased about 4.5 to 4.8 times the ultimate load in plane clay bed.
3. The load capacity increases as the diameter of the granular pile increases.

ACKNOWLEDGMENTS

The tests were performed in the geotechnical engineering laboratory of civil engineering department, MANIT Bhopal. The writers appreciate the support provided by the Head of Department, Professor Dr. Vishnu Prasad.

Notation

The following symbols are used in this paper:

D_{10}, D_{30}, D_{60} = Effective Sizes;
C_u = Uniformity Coefficient;
C_c = Coefficient of Curvature
L.L. = Liquid Limit
P.L. = Plastic Limit
P.I. = Plasticity Index
PC = Plain Clay
GP = Granular Pile
EGP = Encased Granular Pile

REFERENCES

[1]. T. Ayadat, and A.M. Hanna, 2005. "Encapsulated stone columns as a soil improvement technique for collapsible soil." *Ground Improvement*, **94**, 137.

[2]. N.P. Balaam and J.R. Booker, 1981. "Analysis of rigid rafts supported by granular piles." *Int. J. Numer. Analyt. Meth. Geomech.*, **54**, 379–403.

[3]. R.D. Barksdale and R.C. Bachus, 1983. "Design and construction of stone columns." *Rep. Prepared for Federal Highway Administration Office of Engineering and Highway Operations Research and Development Washington, D.C. Rep. No. FHWA/RD-83/026*, FWHA, Office of Engineering and Highway Operations Research and Development, Washington, D.C.

[4]. J.A. Black, V. Sivakumar, M.R. Madhav and G. A. Hamill, 2007. "Reinforced stone columns in weak deposits: Laboratory model study." *J. Geotech. Geoenviron. Eng.*, **1339**, 1154–1161.

[5]. Indian Standard IS: 2003. "Design and construction for ground improvement-Guidelines. Part 1: Stone columns." *IS: 15284*, Bureau of Indian Standards, New Delhi, India.

[6]. S. N. Malarvizhi and K. Ilamparuthi, 2007. "Comparative study on the behavior of encased stone column and conventional stone column." *Soil Found.*, **475,** 873–886.

[7]. J.M. McKenna, W.A. Eyre and D.R. Wolstenholme, 1975. "Performance of an embankment supported by stone columns in soft ground." *Geotechnique*, **251**, 51–59.

[8]. S. Murugesan and K. Rajagopal, 2007a. "Model tests on geosynthetic encased stone columns." *Geosynthetic. Int.*, **246**, 349–358.

[9]. S. Murugesan and K. Rajagopal, K.2007b. "Model tests on stone columns subjected to lateral soil movement." *Proc., 13th Asian Regional Conf. on Soil Mechanics and Geotechnical Engineering*, Vol. **1**, Allied, New Delhi, India, 989–992.

[10]. S. Murugesan and K. Rajagopal, 2009. "Shear load tests on stone columns with and without geosynthetic encasement." *Geotech. Test. J.*, **321**, 35–44.

[11]. M. Raithel, H.G. Kempfert and A. Kirchner, 2002. "Geotextile encased columns for foundation of a dike on very soft soils." *Proc., 7th Int. Conf. on Geosynthetics*, Swets & Zeitlinger, Nice, France, 1025–1028.